

Measurement of Rattle Behavior and Backlash Modeling in Automatic Transmissions

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In automatic transmissions (ATs), expanding the lock-up area or adopting a torque-converter-less structure can improve environmental and driving performance, but this also increases the risk of rattle noise. Since multiple backlash elements exist in series inside an AT, and these backlash elements interact with one another to generate rattle behavior, the development of effective countermeasures becomes challenging. In this study, rattle behavior inside the AT was measured, and a 1D drivetrain model capable of reproducing the observed rattle behavior was developed. Using this model, the effects of each backlash on the overall system behavior were analytically evaluated, and an effective approach for reducing backlash collision velocity was proposed.

For the target AT unit, it was found that under low-load operating conditions, rattle noise is triggered by collisions occurring at the backlash locations on both ends of the shaft shown in Figure 1. To capture the rattle behavior of both the spline backlash and clutch backlash, angular velocities were measured at three locations (Parts A, B, and C). A rotational pulse detection method was employed for angular velocity measurement. To ensure a sufficiently high sampling frequency while minimizing measurement noise, the pulse gear tooth count and rotational speed conditions were optimized.

The entire transmission was modeled as a 1D drivetrain system, and equivalent torsional stiffnesses were assigned to the spline backlash and clutch backlash so that the measured rattle behavior could be accurately reproduced. Figure 2 compares the relative angular velocity across the backlash obtained from measurements and simulations. The simulation successfully reproduced backlash collision velocities with high accuracy.

Countermeasures were investigated using the developed model. An analysis of the rattle mechanism revealed that collisions at the spline backlash increased the collision velocity on the drive side of the clutch backlash. Figure 3 shows the effect of varying the spline backlash clearance. The results indicate that reducing the collision velocity at the spline backlash also leads to a reduction in the collision velocity at the clutch backlash.

Finally, a vehicle test was conducted with the spline backlash fixed by a scissors ring, and the resulting interior noise was evaluated. The results confirmed that interior noise could be reduced by up to 15 [dB], as shown in Figure 4.

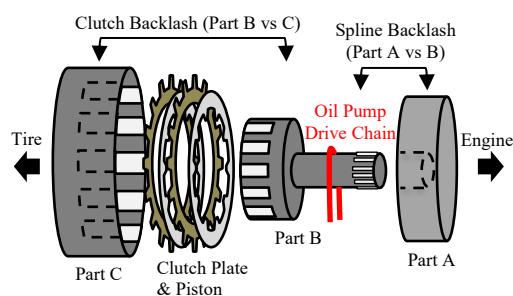


Fig.1 Target Backlash

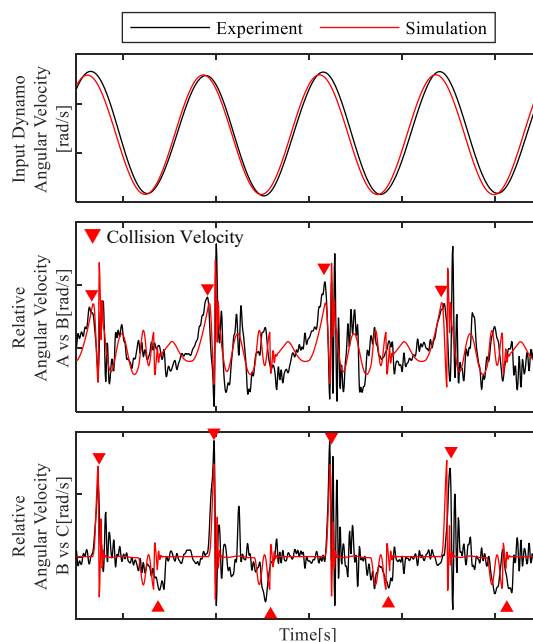


Fig.2 Comparison of Measured and Simulated Rattle Behavior

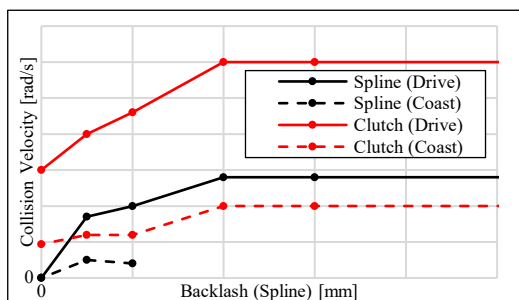


Fig.3 Spline Backlash Study

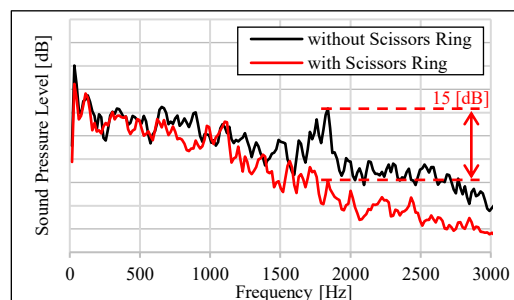


Fig.4 Effectiveness of Countermeasures against Spline Backlash